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On the possible existence of a zero-spin excited state in Ca^{42}

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With 2 figures in the text

ABSTRACT

The 0.3 Mev–1.5 Mev gamma cascade in Ca^{42} has been investigated by angular correlation measurements. It has been shown that the second excited level is probably a 0+ spin state and that the 0.3 Mev transition has $E2$ character.

Introduction

The beta decay of K^{42} into Ca^{42} has been extensively investigated in the last few years. Recently Pohm *et al.* [1] who also give references to earlier published results, have reinvestigated the beta spectrum of K^{42} with improved experimental techniques. As well as data about the well-known beta components of 1.98 Mev and 3.54 Mev end point energies, Pohm also reported a possible weak beta group that has a maximum energy of about 0.5 Mev. The results obtained for the high energy beta spectra confirm previous measurements. Using external conversion techniques refined measurements of the energy of the gamma ray following the 1.98 Mev beta group have given the value 1.53 ± 0.01 Mev. By the same techniques a weak gamma line of 320 ± 5 kev energy was also found. This line has been reported earlier [2]. The intensity of this line is about 0.8 per cent of the 1.53 Mev line. $Ca^{42}(p,p')Ca^{42}$ investigations [3] have given levels at 1.523 Mev and 1.836 Mev. Accordingly it is possible that the two gamma lines are in cascade as their sum energy is close to 1.836 Mev. Fig. 1 shows the tentative decay scheme of K^{42}.

Capeller and Klingelhöfer [4] have reported a gamma-gamma angular correlation measurement of the 0.3 Mev and 1.5 Mev transitions.

In this study we want to report some new results obtained with the angular correlation techniques.

Experimental

The apparatus used has been described earlier [5].

The correlation measurements were performed on K_2CO_3 which had been neutron-irradiated in a reactor.[1] The sample techniques used have already been described [5].

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[1] The sources were kindly provided by AB Atomenergi, Stockholm, Sweden.

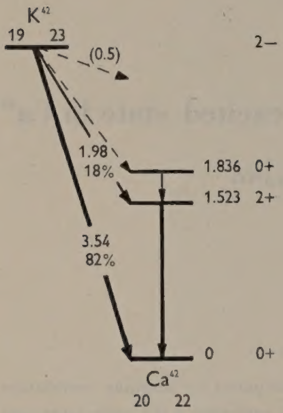

Fig. 1. Tentative decay scheme of K^{42}.

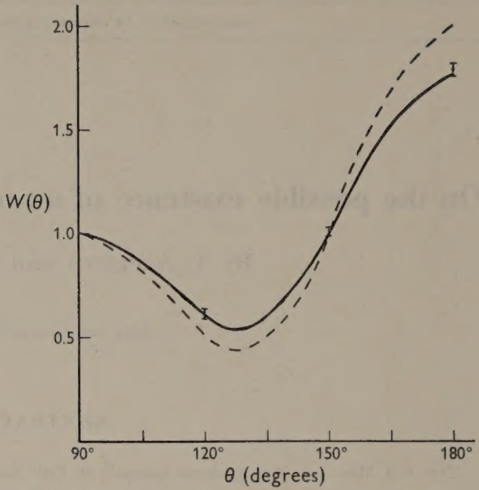

Fig. 2. Experimental and theoretical angular correlation curves. The solid curve represents the least squares fit to the experimental points. The dashed curve is the correlation for the spins 0–2–0.

No chemical separation was made of the neutron-irradiated material as the activities of all possible impurities were probably very weak. Na^{24} was the most critical contaminating isotope but was not considered too serious as single channel analyzers were used for the selection of the 0.3 Mev and 1.53 Mev gamma components of Ca^{42}.

The beta particles emitted by K^{42} were absorbed in aluminum. As the intensity of the 0.3 Mev gamma ray is very small relative to the 1.5 Mev gamma ray a lot of disturbing 1.98 Mev beta Bremstrahlung–1.5 Mev gamma coincidences may be expected.

As the life-time of the 1.5 Mev level is presumably very short, the correlation is not expected to be disturbed because of electric quadrupole or similar interactions.

Observations were made at the following settings of the counter angle: ±90°, ±120°, ±150°, and 180°. Fig. 2 shows the result of measurements on numerous different samples. The solid curve represents the least squares fit to the experimental points. The experimental coefficients A_2 and A_4 in the Legendre polynomial $W(\theta) = 1 + A_2P_2(\cos\theta) + A_4P_4(\cos\theta)$ are

$$A_2 = 0.25 \pm 0.02 \quad \text{and} \quad A_4 = 0.85 \pm 0.03.$$

These values are corrected for the finite angular resolution of the scintillation counters.

Discussion

As the Ca^{42} isotope has an even number of neutrons and protons the ground state spin is zero.

The spin of the 1.5 Mev state is very probably 2+ [1]. The 1.836 Mev level may be the second excited state of this nucleus and the spin of that state probably has a value not higher than 4 according to the systematics of even-even isotopes.

Accordingly we may suppose that the spin sequence associated with the transitions of interest in this correlation measurement is of the form $I \rightarrow 2+ \rightarrow 0+$ where I is the spin of the 1.836 Mev level.

A. The spins 4–2–0 give the theoretical coefficients $A_2 = 0.10$ and $A_4 = 0.009$ and are thus eliminated.

B. The sequence 3–2–0 is impossible as A_4 is then always negative or zero.

C. Our experimentally determined coefficient A_4 is 0.85, but if the spins of the states are 2–2–0 the maximum value of A_4 is only 0.33.

D. A spin of 1 of the second state demands a negative A_4.

E. The spin sequence 0–2–0 gives the theoretical coefficients $A_2 = 0.357$ and $A_4 = 1.143$. The agreement between these values and the experimentally found 0.25 and 0.85 is not too good. The dashed curve in Fig. 2 is the correlation for the spins 0–2–0. However, if there is assumed to be an isotropic background of Bremsstrahlung–gamma coincidences, too low A_2 and A_4 values should result. When the experimental data are compared with the theoretical ones for the spins 0–2–0 it is found that an isotropic coincidence background may have disturbed the correlation measurement. It is of course possible that the 0.3 Mev–1.53 Mev correlation measurement has been influenced by other transitions in the de-excitation of Ca^{42} as K^{42} probably emits a low-energy beta group [1]. It is not probable that the experimental anisotropy is related to coincidences caused by Compton scattering between the counters as these were shielded by lead cones in the common way. The angular distribution found is very peculiar and few spin sequences can satisfy it. However, the most probable spins are 0–2–0 as these spins give a quite characteristic angular correlation. Thus we conclude that the 1.836 Mev state of Ca^{42} has zero spin. As both the ground state and the 1.523 Mev excited state of the even-even nucleus Ca^{42} have positive parities the parity of the 1.836 Mev state is also positive. Consequently the 320 kev gamma is a pure electric quadrupole transition.

First excited states of zero spin have been found only in four cases (O^{16}, Ca^{40}, Ge^{72}, Zr^{90}) and second excited states with the same spin value are found in three cases (C^{12}, Ge^{70}, Pd^{106}) [6–13]. O^{16}, Ca^{40}, and Zr^{90} have closed shells of both protons and neutrons. The other nuclei have one closed sub-shell. As Ca^{42} has also one closed shell it may be assumed that the second excited state of this nucleus has $0+$ character, too. Low-lying $0+$ states in nuclei with two closed shells are probably due to two-particle excitation [6]. Such an explanation may also be applicable to Ca^{40}.

It has already been mentioned that the known number of excited levels of $0+$ spin is very small and consequently the half-life of such levels has been measured directly only in a few cases. Accordingly it would be very interesting if the partial half-lives of interval conversion or nuclear pair emission in Ca^{42} could be measured.

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REFERENCES

1. A. V. Pohm, R. C. Waddell, and E. N. Jensen, Phys Rev. *101*, 1315 (1956).
2. N. H. Lazar and P. R. Bell, Phys. Rev. *95*, 612 (1954).
3. P. M. Endt and C. M. Braams, Rev. Mod. Phys. *29*, 683 (1957).
4. U. Cappeller and R. Klingelhöfer, Z. Naturf. *9a*, 1052 (1954).
5. I. Asplund and T. Wiedling, to be published.

6. G. Scharff-Goldhaber, Phys. Rev. *90,* 587 (1953).
7. L. I. Schiff, Phys. Rev. *98,* 1281 (1955).
8. R. D. Bent, T. W. Bonner, and J. H. McCrary, Phys. Rev. *98,* 1325 (1955).
9. J. C. Bowe, M. Goldhaber, R. D. Hill, W. E. Meyerhof, and O. Sala, Phys. Rev. *73,* 1219 (1948).
10. O. E. Johnson, R. G. Johnson, and L. M. Langer, Phys. Rev. *98,* 1517 (1955).
11. H. W. Kendall, Phys. Rev. *109,* 861 (1958).
12. D. E. Alburger, Phys. Rev. *109,* 1222 (1958).
13. D. E. Alburger and B. J. Toppel, Phys. Rev. *100,* 1357 (1955).

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